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Baltic InteGrid review: towards a meshed offshore grid in the Baltic Sea. Final Report

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Baltic InteGrid

Integrated Baltic Offshore Wind Electricity Grid Development

Baltic InteGrid: towards a meshed offshore grid in the Baltic Sea

Summary report

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Baltic InteGrid:

towards a meshed offshore grid in the Baltic Sea

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Foreword

In response to climate change and the urgent need to shift to a low-carbon energy system, the European Union has set out to foster renewable energy development and further market interconnection, reducing emissions by 80% to 95% by 2050 in the process.

Offshore wind energy is crucial to reaching this renewable energy future. Boasting a higher generation capacity and more full load hours than onshore wind, the sector has achieved remarkable cost reductions in recent years. The Baltic Sea has great potential in this regard, thanks to a range of favourable conditions like shallow waters, strong winds and short distances to shore.

With 2.2 GW of installed capacity and rising, the offshore wind market in the Baltic Sea is on the cusp of accelerated development. Now is the time to explore state-of-the-art solutions for the connection and distribution of offshore wind energy. A meshed grid is one such solution: combining interconnector infrastructure with export cables, a meshed offshore grid in the Baltic Sea would boost the interconnection of electricity markets, and ensure a high utilisation rate for cable infrastructure. Moreover, the installation, maintenance and service sector around a meshed offshore grid could help the Baltic Sea Region excel in green technologies and innovation while creating jobs for local populations.

A guiding hand from policy-makers is needed to tap into the potential of a meshed offshore grid and alleviate the complexity that surrounds its multilateral and capital-intensive nature. Considering the long lead times of offshore wind farms and grid projects, interest in meshed offshore grids must translate into bold policy-making and reinforced transnational cooperation soon, before the region is further locked into a suboptimal energy system.

The Baltic Sea Region has the potential to be a major player in innovative offshore wind technologies and grid solutions. It is high time to start planning for that future, together.

Anika Nicolaas Ponder
Project manager
on behalf of the Baltic InteGrid consortium

Publications

Policy & Regulation

- Establishing a meshed offshore grid: policy and regulatory aspects and barriers.
- European and national offshore wind energy policy in the Baltic Sea Region – A regional status report.
- Legal and policy framework for power transmission and offshore wind power generation in Finland.
- International cooperation on the expansion of offshore wind generation capacity.
- Institutional framework for the development of offshore wind power projects.
- Economic considerations on the regulatory framework for offshore wind and offshore meshed grid investments.

Market & Supply Chain

- Qualified overview paper.
- Market analysis of the offshore wind energy transmission industry.
- Supply chain analysis of the offshore wind energy transmission industry.
- Assessment of Baltic hubs for offshore grid development: A report for the Baltic InteGrid project.
- Baltic Offshore Grid SME business cases: A report for the Baltic InteGrid project.

Technology & Grid Design

- Offshore wind power plant technology catalogue.
- Lifetime estimation and performance evaluation for offshore wind farm transmission cables.
- Optimum sizing of offshore wind farm export cables.
- Metaheuristic-based design and optimization of offshore wind farm collection systems.

- Optimization of electrical infrastructure in offshore wind farms: A review.
- Heuristics-based design and optimization of offshore wind farms collection systems.
- Improved method for calculating power transfer capability curves of offshore wind farm cables.

Environment & Society

- Impact mitigation strategy of the Baltic Offshore Grid.
- Maritime spatial planning and the Baltic Offshore Grid: Status of the MSP process and grid variants.

Spatial Planning

- Towards a Baltic Offshore Grid: Connecting electricity markets through offshore wind farms.
- Recommendations to the ENTSO-E's Ten-Year Network Development Plan.
- Recommendations for the maritime spatial planning process.
- Paving the way to a meshed offshore grid: Recommendations for an efficient policy and regulatory framework.

Cost-Benefit Analysis

- Cost-benefit analysis for an integrated offshore grid in the Baltic Sea.

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Introduction

This publication is a summary of the major findings and insights of the Baltic InteGrid project. Implemented from 2016 to 2019 to explore the potential of meshed offshore grids in the Baltic Sea Region, this project contributed valuable research and analyses relevant to the further integration of regional electricity markets and security of supply around the Baltic Sea. The project activities were designed to correspond to the priorities of the European Union's (EU's) energy policy, which aims to unify the energy markets of the Member States and facilitate a safe and sustainable transition to renewable energy.

Partners

The project was implemented by a consortium of 14 project partners from all eight EU Member States in the Baltic Sea Region. It was supported by 35 Associated Organisations, which included transmission system operators, investors in offshore wind farms, private companies, and a range of agencies and institutions active in research and development.

www.baltic-integrid.eu

Baltic InteGrid

Based on Baltic InteGrid scenarios, the potential of offshore wind in the Baltic is estimated to be 9.5 GW by 2030 and as much as 35 GW by 2050. This new capacity will require a great deal of additional transmission infrastructure. If the expansion is not carefully managed and coordinated, there will be a risk of a proliferation of radial configurations and an accompanying glut of export and interconnector submarine cables. This would be inefficient, possibly leading to higher costs for end users, while also potentially causing significant conflicts with other marine and seaside uses.

The Baltic InteGrid project has concluded that the deployment of new offshore wind infrastructure should therefore be accompanied by meaningful coordination between the countries and stakeholders involved. It is important to consider this well in advance of the coming expansion, as the lock-in effects of an inefficient grid design could be difficult or impossible to correct in the future.

To accompany the coming evolution, the Baltic InteGrid project produced several sets of concrete recommendations, which aim to secure and organise maritime space, ensure consistency between policies, facilitate cooperation among stakeholders, and raise awareness and acceptance among the public. Concretely, the recommendations call for dynamic procedures that are updated whenever necessary, robust frameworks for international and inter-agency cooperation, the involvement of stakeholders from all sectors in planning, suitable legislative and administrative frameworks for the construction and operation of infrastructure, environmental protection guarantees, and advance plans for specific standalone projects that can gradually be rolled out and eventually merged into a single meshed grid linking significant portions of the Baltic Sea Region by 2050.

While this may seem like a distant future, the sector is evolving fast and such a large-scale transformation needs to be carefully prepared. The Baltic InteGrid project provides a range of constructive perspectives, themes and avenues of thought for stakeholders and policy-makers in the Baltic Sea Region to consider when formulating both an overarching vision and specific solutions in the service of laying the foundations for a better energy future. One such perspective is the outline of a meshed grid in the Baltic Sea to be realised by 2050, tentatively named BOG 2050.

Offshore wind in the Baltic Sea

In December 2018, there were eighteen offshore wind farms operating in the Baltic Sea waters with a total installed capacity of 2.2 GW: nine in Denmark, two in Finland, four in Germany and three in Sweden. Many more projects are being planned in all Baltic Sea Region (BSR) countries. For instance, three new projects in Germany are expected to be implemented by the end of 2022, adding 733 MW to total installed capacity.

Emission reductions can be perfectly compatible with economic growth: as part of its transition to a low-carbon society, the EU has reduced greenhouse gas emissions by 22% since 1990, even as its gross domestic product has increased by 50%. The Paris climate agreement, which was adopted in 2015 and will come into force in 2020, has boosted public awareness of the hidden costs of overreliance on fossil fuels and the potential economic benefits of clean technologies. Accordingly, the share of renewable power consumption in EU Member States has been rising continuously over the years.

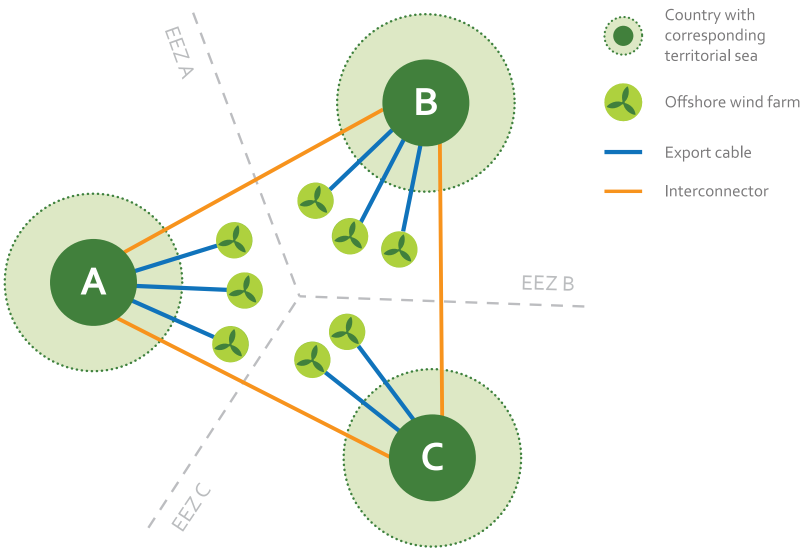
Plentiful wind, long coastlines and shallow waters make the Baltic Sea Region (BSR) a highly attractive area for cost-effective offshore wind farms. Its location at the crossroads of several Member States on the geographical edge of the EU is also linked with great potential for strategic cooperation. However, the BSR also faces significant barriers to the integration of regional markets, including the presence of several

[1] A synchronous grid is a three-phase electric power grid at regional scale that operates at a synchronised frequency and is electrically tied together during normal system conditions.

different synchronous electrical power systems[1] and insufficient transmission infrastructure. The intermittent nature of wind furthermore means that the planned expansion of offshore wind energy in the Baltic Sea will require substantial adjustments to the capacity and design of electrical grids.

A meshed offshore grid

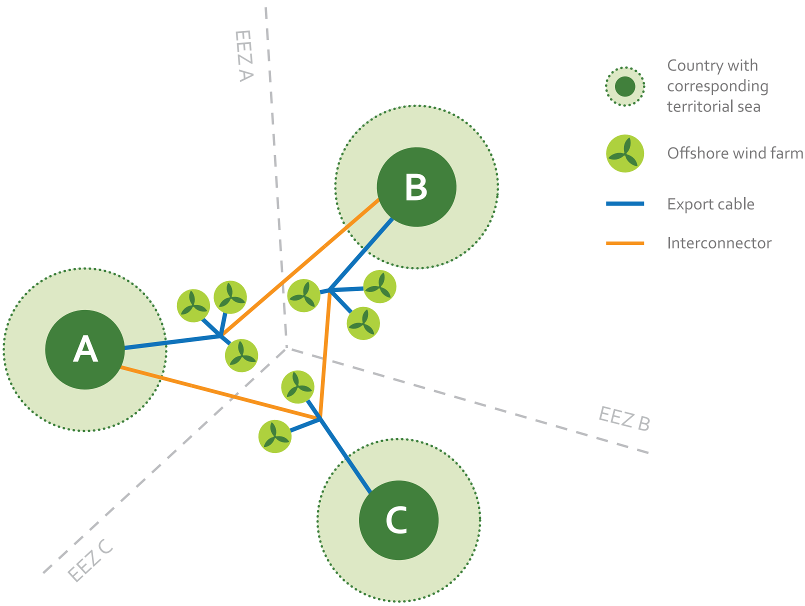
The standard approach to transmitting power from offshore wind farms to shore is to have each installation linked to the grid of the host country (that is, the country in whose territorial waters or exclusive economic zone (EEZ) the wind farm is located) with export (park-to-shore) cables. Such so-called radial connections have the advantage of being legally and technically straightforward. However, there are benefits to connecting wind farms to two or more shores through links that double as export cables and cross-border interconnectors. For one thing, this can substantially shorten the distance power needs to be transported before reaching the end consumers, and partly sidesteps the issues of public acceptance that can affect onshore transmission infrastructure.



Radial connections

The Baltic InteGrid project analysed policy, administrative, technological, planning and market-related issues affecting the design and implementation of meshed grid solutions, and conducted cost-benefit analyses and pre-feasibility studies.

This showed that, in many ways, a meshed grid would be the best method to ensure that the additional power generated offshore in the Baltic in the coming decades can reach end users as efficiently as possible. Such a grid would also strengthen



Meshed grid

interconnections between the countries in the Baltic Sea Region, improving energy security.

This double effect would correspond to the goals of the EU's Energy Union, which aims to safeguard power supply, integrate the EU energy market, improve energy efficiency, help decarbonise the economy and support breakthroughs in low-carbon and clean energy technologies.

Policy and regulatory background

Today's grid design follows the pattern of yesterday's power production. Energy infrastructure in Estonia, Latvia and Lithuania, for instance, reflects their historical dependency on Russia as a major energy provider. In Latvia, there is high power transmission capacity in the east, while the western segments of the grid are unsuited to large-scale power transmission, hampering offshore wind power development.

> Cross-border links among states in the BSR are stymied by the presence of three different synchronous areas – the Continental, Nordic and Baltic. The joint statement of the Heads of State or Governments of the Baltic States of 22 March 2018 affirmed the parties' commitment to disconnecting Estonia, Latvia and Lithuania from the Russia-centred BRELL energy ring and linking them to the continental system by 2025.

A start has already been made on integrating the electricity networks in the BSR through the construction of cross-border transmission infrastructure. Existing links between Poland & Sweden (SwePol, inaugurated in 2000) and Estonia & Finland (Estlink, 2007) announced a new era of interconnection, and were soon followed by others, with several more currently in the pipeline. **In an effort to establish a connected internal energy market and end the isolation of 'energy islands', the EU set an interconnection target of at least 10% of Member States' installed electricity production capacity by 2020 and 15% by 2030. Meshed grid constellations could help achieve this target.**

> The wind energy associations across the BSR have joined in the Baltic Sea Offshore Forum (BaSOF), which advocates for the development of offshore wind energy and the attendant industry in the BSR to strengthen the energy transition and establish a more sustainable and efficient energy market across the region. In September 2017, BaSOF signed the Baltic Sea Declaration with the main European wind power association WindEurope, which calls for regional cooperation in maritime spatial planning, grid development, capacity planning and support schemes.

EU support to renewable energy

The EU facilitates the expansion of renewable energy, including offshore wind, by allowing Member States to provide economic incentives for it as an exception to its usual prohibition on state aid to private companies. Specifically, Member States may promote energy from renewable sources as long as this contributes to the fulfilment of the EU's energy and climate targets; however, such support must not have undue negative effects on competition and trade. In 2017, the European Commission approved the support granted by Denmark to the Kriegers Flak offshore wind farm and concluded that the positive aspects of the project outweighed the potential distortions of competition caused by support from the Danish government.

The EU first set binding targets for sustainable power in its Member States with its Renewable Energy Directive (RED) of 2009. The new

Renewable Energy Directive (RED II) of 2018 specified that at least 32% of EU's energy consumption would come from renewable energy by 2030.

EU instruments and cross-border links

There are several EU instruments specific to energy in the Baltic Sea Region. The EU Strategy for the Baltic Sea Region (EUSBSR) is a macro-regional strategy approved by the European Council in 2009 with the objectives of saving the sea, connecting the region, and increasing prosperity. The connection goal of the Strategy addresses energy policy in particular.

The Baltic Energy Market Interconnection Plan (BEMIP) initiative was signed in 2009 by all eight Baltic Member States and the European Commission with the aim of connecting the BSR to the EU's internal energy market and ending the region's energy isolation. The concrete goals of the BEMIP include setting up an integrated electricity and gas market in the BSR through the development of infrastructure projects for renewable energy and interconnections.

The BEMIP was updated and combined with the Energy Policy Area of the EUSBSR in 2015. The resulting revised common action plan defined measures to be implemented by 2020 in areas such as energy infrastructure, the electricity market, security of supply, energy efficiency and renewable energy.

Priority projects and corridors

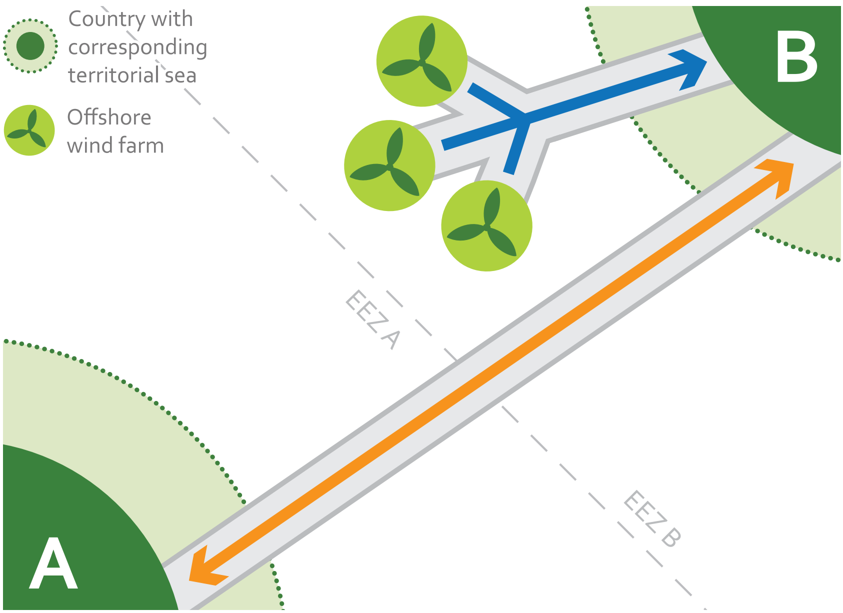
Useful support for cross-border linkages is provided by the introduction of EU interconnection targets and investment in Projects of Common Interest (PCIs); preference is given to projects in priority corridors, as identified in the Trans-European Networks for Energy (TEN-E) strategy. PCIs benefit from accelerated planning and permit granting, improved regulatory conditions, streamlined environmental assessment processes enabling lower administrative costs, and increased visibility to investors. They can also apply for funding from the Connecting Europe Facility (a major EU funding instrument which aims to promote growth, jobs and competitiveness through targeted infrastructure investment at the European level).

EU energy and environmental law

As Member States share competence with the EU in energy and environmental law, much of the legal framework regarding offshore wind energy production represents transpositions of legal provisions set out in EU directives.

Cable operation

It is unclear whether cross-border interconnectors are part of national transmission systems under EU legislation, as they are not explicitly defined. The Electricity Directive states that transmission system operators (TSOs) are 'responsible for operating, ensuring the maintenance of and, if necessary, developing the transmission system in a given area and, where applicable, its interconnections with other systems [...]'. This implies that any interconnector managed by a TSO is by definition part of the relevant national transmission system. The Electricity Regulation furthermore states that factors such as independence requirements apply to interconnectors in the same way as they do for the rest of the transmission grid. In a meshed grid, some cables will function sometimes as an export cable, sometimes as an interconnector – and sometimes even both at the same time, if part of their capacity is used to transport electricity from the offshore wind farm to shore and part to transmit power from one shore to the other.

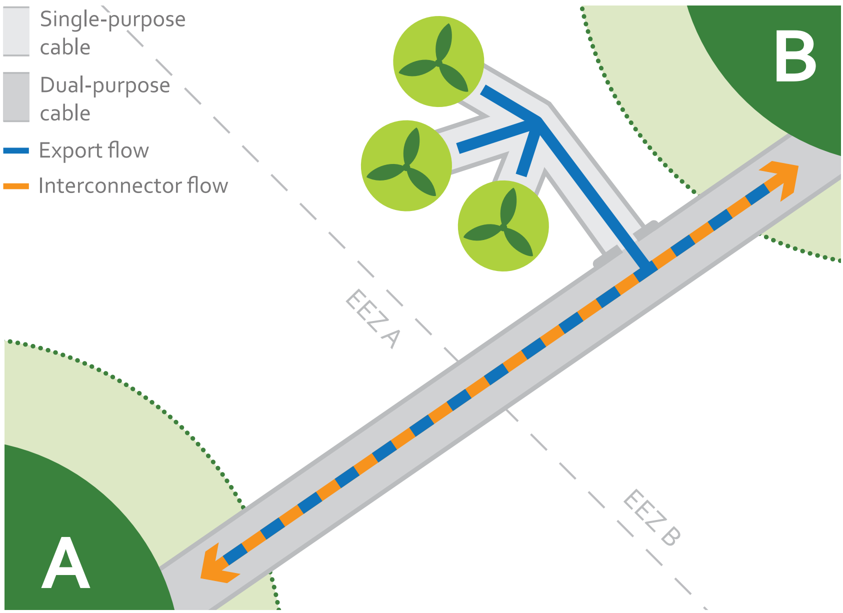


Radial and interconnector cable infrastructure

An example: Kriegers Flak

The differences in legal status between interconnectors and export cables – the fact that they are operated by different actors, say – can make the operation of a meshed grid quite complex, especially if a cable functions as both interconnector and export cable at the same time.

In the Kriegers Flak Combined Grid Solution, the Danish national regulatory authority has determined that electricity transmitted to Denmark from the Kriegers Flak wind farm should have priority access over power arriving from Germany. The reasoning for the decision was that Kriegers Flak should be treated the same as other



Dual purpose cable infrastructure

wind farms in Denmark, and Danish law specifies that power produced by offshore wind farms must be accommodated within the grid. While the decision does not explicitly mention cross-border transmission, in practice it gives priority to power produced by the Kriegers Flak offshore wind farm to the potential detriment of the interconnector function of the cable.

Before meshed grid developments can be more widely implemented, this type of complexity will need to be resolved, and legal definitions that can accommodate a greater number of meshed grid designs adopted.

Planning and construction

Offshore wind is just one of the many different interests and sectors among which maritime space is shared. Maritime spatial planning (MSP) is a crucial tool that allows maritime activities to be coordinated and sectoral interests to be balanced efficiently. This in turn facilitates more sustainable use of marine resources and the exploration of new economic opportunities. The role of maritime spatial plans is to create a formal base for the allocation of maritime space for offshore wind farms and transmission systems, among others, while specifying a range of legal requirements.

Permitting procedures

The permitting procedures for the construction of offshore wind farms and the laying of offshore cables are defined at the national level. In some countries, the transmission lines between the transformer substation and onshore connection point to the transmission grid are built or financed by the operator; in such cases, these cables may be included in the permits. In other countries they are part of the transmission grid and subject to a distinct permitting procedure. This can complicate projects for developers of cross-border projects, especially foreign investors.

Challenges to the construction or operation of offshore wind and related onshore facilities can substantially slow down or complicate the construction of wind farm and grid infrastructure. The risk and repercussions must be carefully considered in the planning phase preceding every project. Third parties whose subjective rights – such as physical integrity or property rights – are affected by the completion of a project can generally challenge a project permit by appealing to an administrative or judicial body to revoke the authorisation. Environmental organisations can challenge a permit without having to experience a violation of a subjective right.

Grid connection

Technical requirements for plant connection to the grid are established at EU level by Commission Regulations (EU) 2016/631 of 14 April 2016 and 2016/1447 of 26 August 2016, while connection claims are governed at the national level. In Denmark, Finland and Poland, for instance, the grid operator is obligated to connect any wind power plant that fulfils the grid connection requirements, and in Germany and Lithuania the TSO must connect renewable energy plants even if the connection requires the grid to be optimised or expanded. Meanwhile, in Estonia, Latvia, and Sweden (under special circumstances), the grid operator may refuse to connect a plant if the grid capacity is insufficient. These varying conditions must be taken into account by developers, and can represent substantial barriers to the smooth operation of offshore wind facilities.

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Environmental issues and public acceptance

Overall, there is strong public support for transitioning to low-carbon energy systems. However, opposition to specific renewable energy projects often emerges at the local level. Opponents are not always motivated by self-interest, fear of development or a failure to understand the importance of combatting climate change. Reasons to oppose renewable energy projects range from specific environmental concerns to a perceived lack of transparency or inclusiveness in the decision-making processes. These must be considered when planning and constructing offshore wind power generation and transmission infrastructure.

Public acceptance of offshore projects can be improved in several ways. For example, integrating public participation mechanisms early on in the planning process can address local mistrust of project developers, of the decision-making process or of the public authorities competent to approve the project. Possible impacts of renewable energy projects can also be mitigated through other incentives, such as offering local populations the option to become financially involved in a project. Another measure that can foster acceptance is to set up local maintenance and service facilities for renewable energy sites, offering jobs and training possibilities to local communities. Such socio-economic benefits can make a valuable contribution towards achieving greater public acceptance of renewable energy projects.

Environmental impact assessments

The EU's Environmental Impact Assessment (EIA) Directive dictates that the environmental impact of projects which are 'likely to have significant effects on the environment' must be assessed. Under its terms, Member States have the choice to carry out EIAs for offshore wind farms or submarine cables if they wish. In practice, there are a range of different methods regarding EIAs among the countries in the BSR.

Components

Wind power generation is based on well-established technology in which Europe has a global edge. There are European producers, suppliers and installers of all components involved in onshore as well as offshore wind power generation and transmission. Technical developments relevant to offshore wind in particular – especially in long-distance power transmission – are ongoing, and are likely to make the related processes more efficient and streamlined.

AC and DC transmission equipment

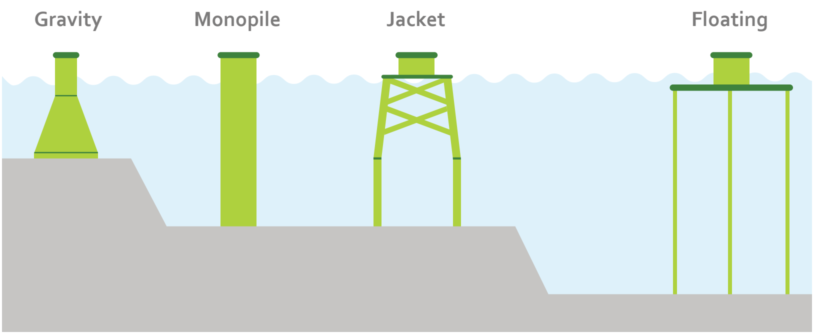
Near-shore wind farms use high-voltage alternating current (HVAC) cables to transmit electricity directly to the onshore AC grid; in the Baltic Sea, this has so far been the most common configuration. Wind farms can, however, also be linked to the onshore grid through high-voltage direct current (HVDC) cables with HVDC converters on both ends. HVDC cables are generally better for transporting large amounts of electrical power over long distances. Moreover, they can be used to transmit power between synchronous grids, three of which intersect in the BSR. While HVDC cables are likely to be applied more and more in the industry, and their price is bound to decrease over time, uncertainty and risks associated with the technology make it challenging to predict demand with precision.

DC technology

The use of HVDC for submarine connections of meshed offshore grids is currently hampered by limitations in the technology, as much of the relevant technology – circuit breakers especially – is not yet commercially mature. The potential applications are highly promising, however.

Offshore substation substructures

Offshore substation substructures are chosen based on a range of variables linked to site conditions and platform properties. The most relevant site conditions are water depth, wave height, soil type and water currents. The main properties of the platforms are size and weight. The final selection is made based on structural and cost-benefit analyses. Basic types of substructures are shown below. The water depth and distance to shore of offshore wind farms have been increasing steadily over the past years. Increasing demand for wind farms built in greater water depths is contributing towards the development of floating foundations, which could enable the installation of offshore wind farms at depths surpassing 100 metres in the medium term.



Models for offshore wind turbine foundations

Operation, maintenance and service

The operation, maintenance and service (OMS) market is expected to provide expanding opportunities to a wide range of established companies and new market entrants. There will be space for new players to compete as long as they offer cost reductions.

Future savings are expected to emerge from developments such as further improvements in weather forecasting; remote monitoring, inspections, and repairs; condition-based monitoring; offshore logistics; and a holistic approach to OMS strategy.

The way forward

A major component of the Baltic InteGrid consisted of two pre-feasibility studies, which aimed to measure the suitability of the meshed grid approach to the Baltic Sea in technological, market-related, environmental and economic terms. For this purpose, the studies compared a meshed-grid configuration with a radial system, considered technical designs and their costs, and provided a comparison of the costs and benefits of the various options. The results of the studies can be extrapolated to other areas of similar size and with similar conditions.

The pre-feasibility studies were carried out for three proposed degrees of integration, two levels of expansion and two hypothetical meshed grid areas – a south-eastern one linking Lithuania, Poland and Sweden and a south-western one between Sweden, Germany and, in the high-deployment scenario, Denmark. The areas were chosen based on high development prospects and an existing pipeline of projects, as well as potential for useful cross-border infrastructure. The proposed connections were also discussed with relevant stakeholders such as transmission system operators (TSOs).

Mapping the future

The first case study covered the south-eastern Baltic Sea. This region was selected for several reasons: there are numerous offshore wind projects planned in the Polish EEZ and several in the Swedish EEZ, and many of those will be close to the border between the two on the Southern Middle Bank. There are also existing submarine interconnectors between Poland and Sweden and between Lithuania and Sweden. The second case study was the south-western Baltic, chosen based on the significant number of offshore wind projects planned in the German portion of the Baltic Sea and the projects under consideration in the Swedish and Danish EEZs close to the border with Germany. Moreover, the Swedish and German TSOs are building an additional interconnector (one has been in place since 1994) named Hansa PowerBridge between the two countries which is expected to be commissioned in 2025. A third link (Hansa PowerBridge 2) is under consideration.

South-eastern Baltic grid

The Baltic InteGrid project found that a meshed grid linking Lithuania, Poland and Sweden would make economic sense in both high and low-expansion settings for offshore wind in the Baltic Sea, with benefits outweighing the costs in all cases. The most advantageous solution in a high-expansion setting – assuming 11.2 GW of capacity added to the Baltic Sea between 2025 and 2045 – would be partial integration, which would provide a net gain of €0.36 billion over the baseline. In a low-expansion setting, the best solution would be maximum integration, with net gains over the baseline of €0.91 billion in all.

South-western Baltic grid

Assuming a given critical mass of generation capacity in the south-western Baltic Sea, a meshed grid would be substantially more favourable than radial connection of offshore wind farms. In the high-expansion setting – assuming 3.7 GW in the whole Baltic Sea added in 2025-2045 – the best scenario would be maximum integration, which would provide gains over the no-integration baseline of €1.81 billion. On the other hand, if expansion falls short of a

[2]*This estimate was formulated before Germany's latest offshore tender; however, the main conclusions of the analysis remain valid.*

certain critical mass (assuming 1.9 GW are added in 2025-2015), integration would not be beneficial. The optimal solution in that case would therefore be the zero-integration scenario, with all projects connected radially to shore.

Technical and strategic benefits

Local meshed grids in the south-western and south-eastern Baltic Sea would have substantial advantages beyond cost efficiency. Higher integration would provide more flexibility with regard to the adequacy rate. It would also lead to shorter combined length of AC and DC cables and therefore lower installation costs (however, it would also require some application of relatively costly HVDC technology and more converter stations on and offshore).

Moreover, integration would promote the process of linking the Baltic States (Estonia, Latvia and Lithuania) to the synchronous grid of Continental Europe and strengthening security of supply.

Finally, the lower number of cables and landfall points (only one third as many in the maximum-integration scenario as in the baseline situation) in a meshed system would potentially lead to higher public acceptance than could be expected for a radial grid.

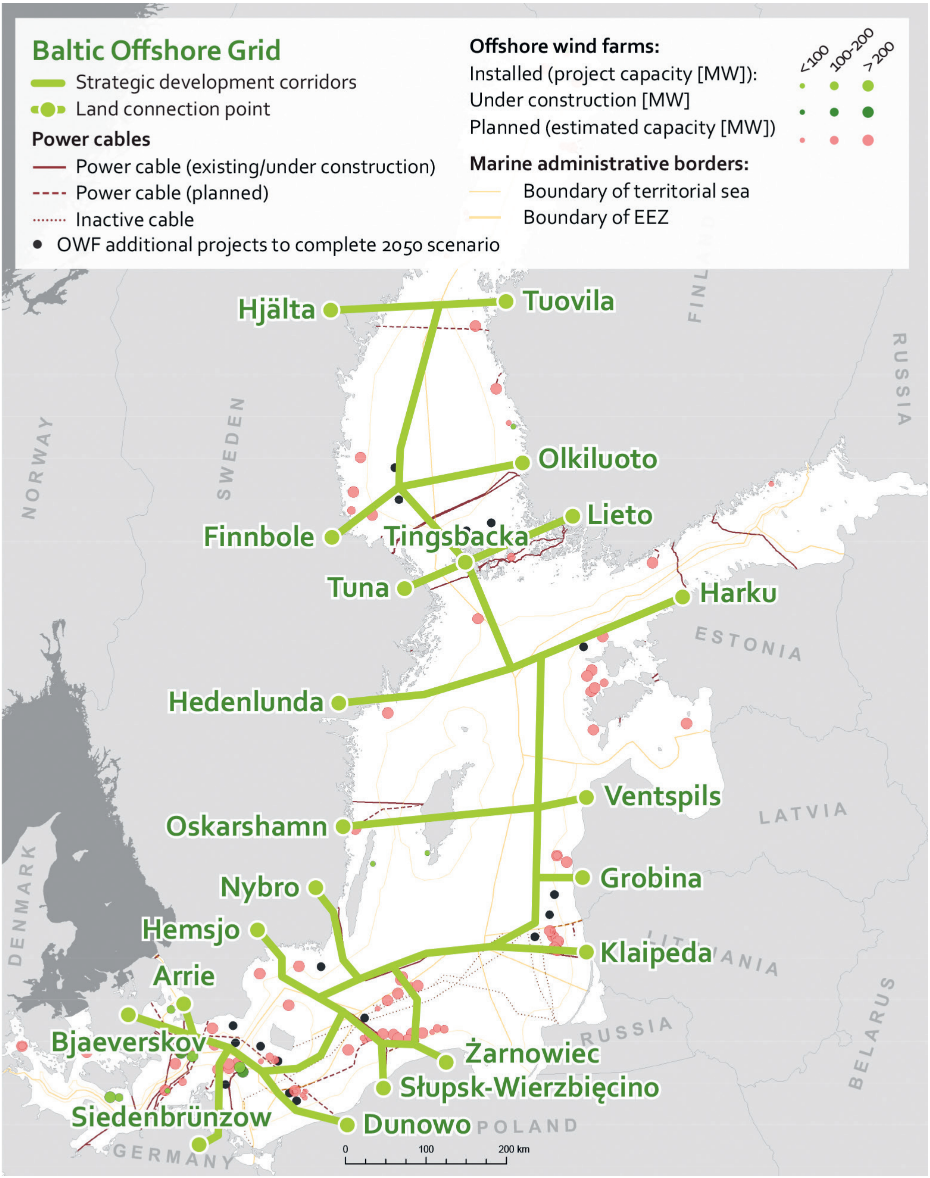
BOG 2050

A concept for a meshed grid in the Baltic Sea has been developed within the Baltic InteGrid project, called the Baltic Offshore Grid (BOG 2050). It is based on the findings of the various groups of activities, especially the study cases, extrapolated to the long term and across the whole Baltic Sea.

BOG 2050 aims to provide a realistic model for achieving a meshed grid in the Baltic Sea. This would entail an improvement of the connections between offshore wind farms in the Baltic Sea and strengthening of cross-border links in line with interconnection priorities pursued by the Energy Union. It would also enable the development of innovative offshore technologies, with intensive research and development carried out to achieve ever-larger, more efficient and cheaper turbines and increased transmission voltages, and the training of multidisciplinary staff in relevant engineering, planning and research programmes, international law, and national regulations.

Description and components

Given current plans for the installation of offshore wind farms and interconnectors, the principal component of BOG 2050 would cover the southern Baltic Sea. Wind farms close to shore would mainly be expected to be connected radially, while the integrated section of the grid would realistically be deployed for wind farms at some distance from shore. A potential secondary focus could be envisaged in the northern part of the Baltic Sea, between Estonia, Finland and Sweden. And a distant third prospect could be considered to link the northern and southern systems through an intermediary configuration situated off the coast of the Baltic States. The figure on the right shows the proposed development corridors.



Baltic Offshore Grid
Strategic development corridors
Land connection point
Power cables
Power cable (existing/under construction)
Power cable (planned)
Inactive cable
OWF additional projects to complete 2050 scenario
Offshore wind farms:
Installed (project capacity [MW]):
Under construction [MW]
Planned (estimated capacity [MW])
<100
100-200
>200
Marine administrative borders:
Boundary of territorial sea
Boundary of EEZ
Hjälta
Tuovila
Olkiluoto
Finnbole
Tingsbacka
Lieto
Tuna
Harku
Hedenlunda
Ventspils
Oskarshamn
Grobina
Nybro
Hemsjo
Klaipeda
Arrie
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Dunowo
NORWAY
SWEDEN
FINLAND
RUSSIA
ESTONIA
LATVIA
LITHUANIA
BELARUS
DENMARK
GERMANY
POLAND
0
100
200 km

Baltic InteGrid Publications

- Bergmann, Ida (Aalto University), Ari Ekroos (Aalto University), Alice Grønhøj (Aarhus University), Pia Isojärvi (Aalto University), Federico Marco (IKEM), Bénédicte Martin (IKEM), Birgitte Egelund Olsen (Aarhus University), Kaarel Relve (University of Tartu), Kanerva Sunila (Aalto University), Hannes Veinla (University of Tartu). (Aalto University). July 2018. Establishing a meshed offshore grid: policy and regulatory aspects and barriers.

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